

Element distribution of high iron-bearing zinc calcine in high gradient magnetic field

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Abstract: High gradient magnetic separation was conducted in order to separate insoluble zinc ferrite from zinc calcine before acid leaching of hydrometallurgical process. Chemical composition and structural characterization of zinc calcine were studied via inductively coupled plasma (ICP), X-ray diffraction (XRD), Mössbauer spectra, scanning electron microscopy (SEM) and laser particle analysis (LPA). The parameters of magnetic separation which affect the distribution of zinc ferrite and undesired elements, such as calcium, sulfur and lead in magnetic concentrate were investigated. The results of high gradient magnetic separation indicate that more than 85% of zinc ferrite is distributed into magnetic concentrate from the zinc calcine under the magnetic induction of 0.70 T. In addition, about 60% of calcium and 40% of sulfur distribute in non magnetic phases of tailings during magnetic separation process. Most of lead distributes uniformly along the zinc calcine in superfine particle size.

Key words: zinc calcine; zinc ferrite; magnetic separation; element distribution

1 Introduction

Zinc is an important metal required for various applications in metallurgical, chemical and textile industries [1]. At present, the roast-leach-electrowin process accounts for the greatest share of the world zinc production [2,3]. One of the major concerns related to this typical process is the zinc ferrite produced as a byproduct in the oxidative roasting of iron-bearing zinc sulfide concentrates through the reaction of zinc oxide with hematite. About 15% of zinc ferrite which is practically insoluble under dilute acidic conditions was produced in a traditional metallurgical process and became the dominant components of zinc leaching residue. The zinc leaching residue contains a variety of heavy metals, such as lead, cadmium and chromium, and is classified as a hazardous waste by environmental protection agencies.

Pyrometallurgical and hydrometallurgical processes are usually applied to treating such residue. An ordinary pyrometallurgical method is Waelz process, in which

zinc leaching residue is heated above 1300 K with coke or powdered coal in a horizontal reducing rotary kiln, known as the Waelz furnace [4]. The zinc and other volatile non-ferrous metals in the residue are vaporized in the kiln and then reoxidized and collected as a crude zinc-bearing product which are further refined and subject to acid leaching. A major disadvantage of pyrometallurgical method is high-energy consumption, application of complicated dust collecting and gas cleaning system and difficulty for iron recovery due to the high hardness of sintering waste contributed by metallic iron generated in the reducing process.

On the contrary, hydrometallurgical process obtains more attention on account of its cost-effective and environmental-friendly advantages. Various leaching solutions including hot sulfuric acid, hydrochloric acid [5,6] and alkaline [7,8] have been investigated and a considerable amount of optimum conditions have been obtained during past decades. In addition, a number of new methods with a combination of pro-hydrometallurgical process have been proposed recently. During these processes, the zinc leaching residue was

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roasted with one or several addition agents to make zinc ferrite transfer into soluble zinc salt and then followed by water leaching, acid leaching or alkaline leaching [9–11]. However, a major drawback of the hydrometallurgical process is that iron dissolved in undesired metal during the leaching process. Therefore, iron constitutes a serious impurity in zinc solutions and must be removed before electrolysis. To overcome this problem, several methods have been conducted to separate iron from zinc solution, such as precipitation of iron as goethite, hematite or even jarosite. Furthermore, oxidative leaching has also been employed to remove iron from solution [12].

There is no reference on separation of zinc ferrite from zinc calcine before acid leaching up to now, although many studies on zinc leaching residue to decompose zinc ferrite and recover metals have been reported. A high gradient magnetic separation was proposed to remove zinc ferrite from zinc calcine according to the weak magnetic properties of zinc ferrite, which will reduce the iron precipitation burden for traditional dilute sulfuric acid leaching and shorten the leaching flow process. However, the distribution of elements in zinc calcine is unclear. This study focused on the characteristics of zinc calcine and the behavior of impurity elements distribution during the high gradient magnetic separation process. The distribution correlation between magnetic induction and magnetic mineral phases was detected for developing magnetic separation methods to treat the high iron-bearing zinc calcine or zinc leaching residue.

2 Experimental

The sample of zinc calcine used in this study was obtained from a zinc plant in Inner Mongolia, China. It was homogenized, dried and sieved to obtain <74 μm fraction, and then prepared by dissolving in an acid admixture for the determination of metal content using inductively coupled plasma (ICP-OES, IRIS Intrepid II XSP). The phases present in zinc calcine were detected by X-ray powder diffraction (Rigaku, TTR-III) in the pattern of monochromated Cu K_{α} radiation in 2θ from 10° to 80° with a scan step of 0.05° and the data were analyzed by using JADE 5.0 X-pert software. The phase composition of iron was investigated by Mössbauer spectra on a standard spectrometer at constant acceleration and room temperature. A 70 mCi $^{57}\text{Co}(\text{Gr})$ source was used and the isomer shifts were given relatively to that of $\alpha\text{-Fe}$. The spectra obtained in the experiments were analyzed using standard software based on the least-squares method. Scanning electron microscopy (JEOL.LTD, JSM-6360LV) was used to gain further information of structure, morphology and chemical composition of the zinc calcine to help

commanding the distribution of elements. The particle size distribution and the average diameter of zinc calcine particles were evaluated by a laser particle size analyzer (MICRO-PLUS).

The magnetic separation was performed on the slurry of zinc calcine with the solid to liquid ratio of 1:5, using a high gradient magnetic separator under electromagnet working at a high magnetic induction from 0.1 to 1.65 T. A sample of 50 g was used in each magnetic separation experiment. The concentrates and tailings were collected, dried, weighed and analyzed for metals, respectively. The distribution rate and grade of metals in concentrates were tested to evaluate the distribution properties of main elements in zinc calcine.

3 Results and discussion

3.1 Characterization of high iron-bearing zinc calcine

ICP analysis was performed to determine the chemical content of metals in received zinc calcine. The average composition is given in Table 1. From the ICP results, the sample contains approximately 57% zinc, 12% iron, 1.27% lead and 2.44% sulfur as major elements. Besides, the zinc calcine also presents intermediate amounts of Mn, Ca, Al, Cu and trace amount of toxic element such as cadmium.

Table 1 Chemical composition of zinc calcine analyzed by ICP (mass fraction, %)

Mg	Al	S	Ca	Mn	Fe	Cu	Cd	Pb	Ag	Zn
0.20	0.24	2.44	0.57	0.53	12.1	0.91	0.15	1.27	0.014	57.37

The X-ray powder diffraction (XRD) pattern of the zinc calcine is shown in Fig. 1. Based on the peaks detected and their respective intensities, it can conclude that the zinc calcine consists of the major phases of zincite (ZnO), zinc ferrite (ZnFe_2O_4), willemite (Zn_2SiO_4), zinc sulfide (ZnS) and magnetite (Fe_3O_4). However, the signals from zinc ferrite and magnetite exhibit overlapping in all peaks, as shown in Fig. 1. Such

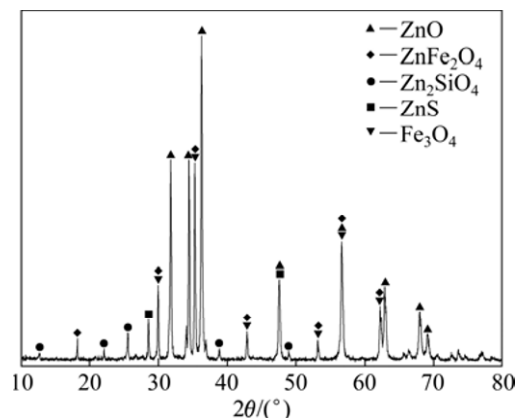


Fig. 1 X-ray diffraction pattern of zinc calcine

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